US Department of Energy - OHEP
Accelerator Task Force

Interim Report to HEPAP

N.Holtkamp (SLAC)
March 12, 2012

The *Accelerators for America's Future* Workshop in 2009

A MESSAGE FROM THE CHAIRS

In October 2009, the Department of Energy's Office of High Energy Physics sponsored a symposium and workshop," Accelerators for America's Future." Its purpose was to elicit the views and opinions of a wide range of accelerator users on the challenges and opportunities for developing and deploying accelerators to meet national needs.

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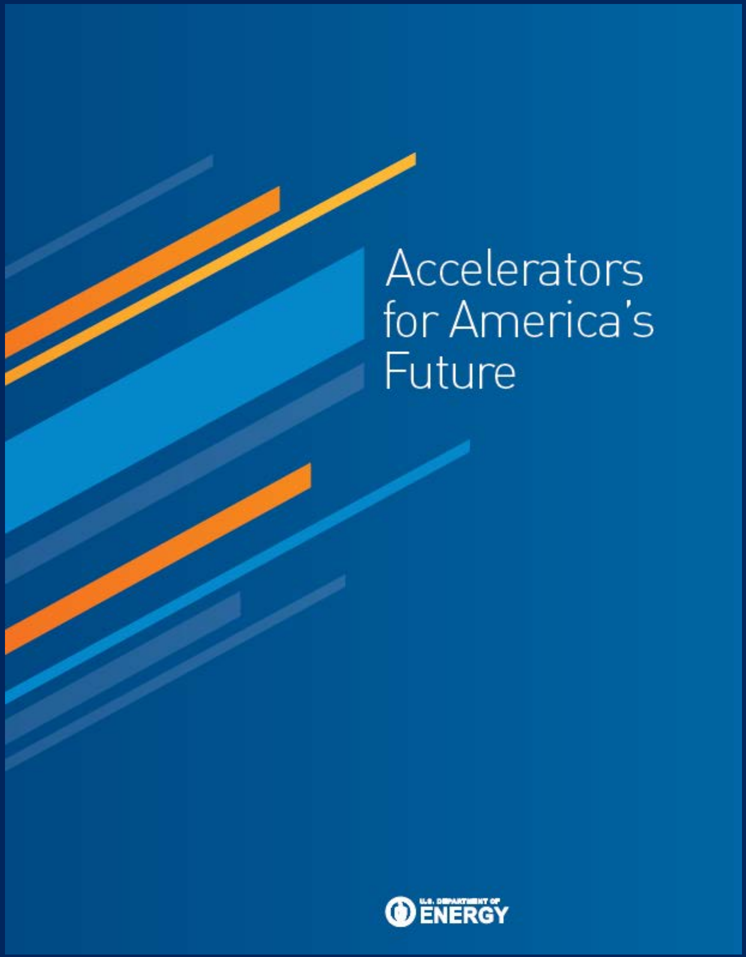
W. Henning. C. Shank



Why are we here?
Senate mark-up

"The Committee understands that powerful new accelerator technologies created for basic science and developed by industry will produce particle accelerators with the potential to address key economic and societal issues confronting our Nation. However, the Committee is concerned with the divide that exists in translating breakthroughs in accelerator science and technology into applications that benefit the marketplace and American competitiveness."

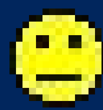
"The Committee directs the Department to submit a 10-year strategic plan by June 1, 2012 for accelerator technology research and development to advance accelerator applications in energy and the environment, medicine, industry, national security, and discovery science. The strategic plan should be based on the results of the Department's 2010 workshop study, Accelerators for America's Future, that identified the opportunities and research challenges for next-generation accelerators and how to improve coordination between basic and applied accelerator research. The strategic plan should also identify the potential need for demonstration and development facilities to help bridge the gap between development and deployment."

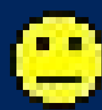
Who are we – why us?

Sandra Biedron	Colorado State University
Lester Boeh	Varian Medical Systems
James Clayton	Varian Medical Systems
Stephen Gourlay	LBNL
Robert Hamm	R&M Tech. Enterprises, Inc.
Stuart Henderson	FNAL
Georg Hoffstaetter	Cornell
Norbert Holtkamp	SLAC
Lia Merminga	TRIUMF
Stephen Milton	Colorado State University
Satoshi Ozaki	BNL
Fulvia Pilat	JLab
Marion White	ANL
George Zdasiuk	Varian Medical Systems
Michael Zisman	DOE-HEP

- It is a small group
- There was about 3-4 month of time
- Tried to include the main players, DOE, NSF, Universities, Industry

Charge from Jim Siegrist, AD
US DOE Office of High Energy Physics

1. Summary of costs and time scales for previous successful accelerator R&D efforts to help us assess future funding profiles;

2. Identification of those research opportunities that might have a strong potential for broad national benefits with relevance to the areas of energy and the environment, medicine, industry, national security and discovery science, along with the reasons why you believe they do;

3. A summary, including an estimate (based on your knowledge and expertise) of the current scope of work, resources invested, and status of the key research and technology areas identified, and;

4. Identification of possible impediments (both technical and otherwise) to achieving successful demonstration; in particular, note as appropriate the underlying fundamental science challenges that need to be addressed, and how these relate to use-inspired and applied R&D.


What did we do? How did we do it? Why are we here today

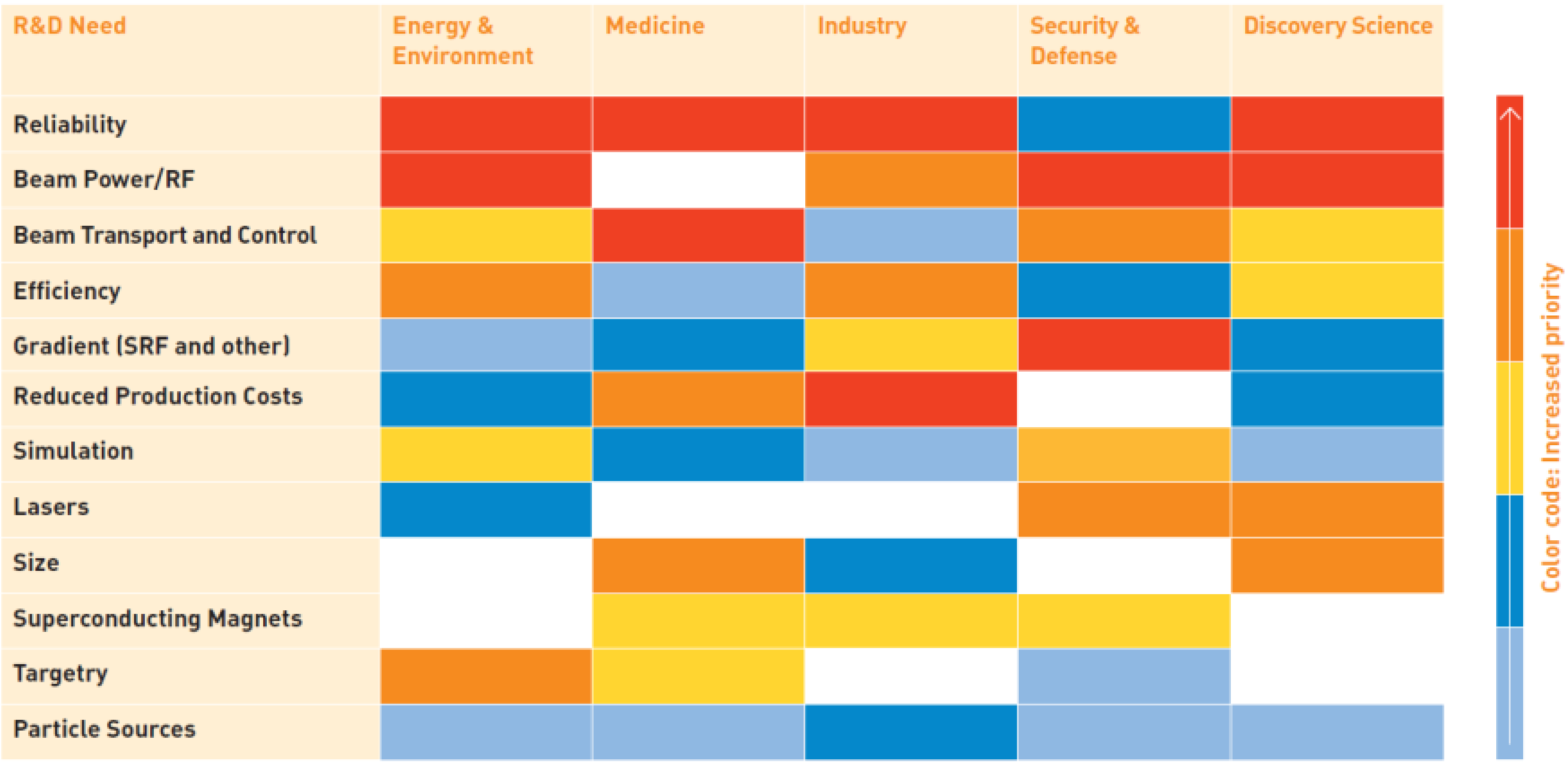
https://slacportal.slac.stanford.edu/sites/ad_public/committees/Acc_RandD_TF_Blog/default.aspx

- DOE was asked the question by congress and will have to respond
- The process has to include the major player or it will be unsuccessful
- There were three panels already: ‘86 Tigner, ‘96 Marx, ’06 Marx.

Share our Goal: engage with customers through the science we deliver—have the customer promote our science since it adds value to them

Results from *Accelerators for America's Future* Workshop

Areas of R&D identified by each working group. All areas are of importance to each working group. Color coding indicates areas with greatest impact.



Courtesy: W. Henning, C. Shank

The Grand Challenges

1. **Extend the energy reach of collider technology to probe fundamental phenomena at the multi-TeV scale → *High Energy***
2. **Extend the beam power and intensity reach of hadron accelerator technology to enable next-generation capabilities in fundamental physical sciences and applications in energy → *Beam power***
3. **Extend the capability and understanding of performance limits of RF accelerating structures and technology → *High Gradient***
4. **Break the "RF Barrier" by developing scalable next-generation acceleration methods in the 10 GeV/meter range → *New Acceleration Methods***
5. **Develop tools and technologies for the manipulation of particle beam phase-space and the exploration of limitations to beam emittance → *Beam Emittance***
6. **Develop concepts and technologies to extend the brightness, brilliance and coherence of photon sources to meet the challenges of 21st century materials science → *Brightness & Coherence***
7. **Develop accelerator systems to serve as compact sources of photons, neutrons, protons and ions → *Compact Accelerators***

Hit the road running…

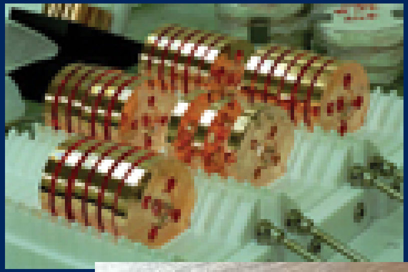
The Seven Grand Challenges of Accelerator Physics

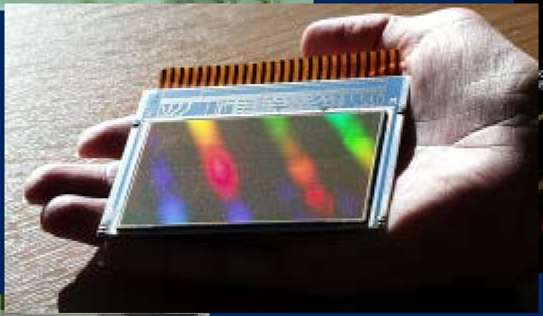
Connecting the dots: From Science to Application

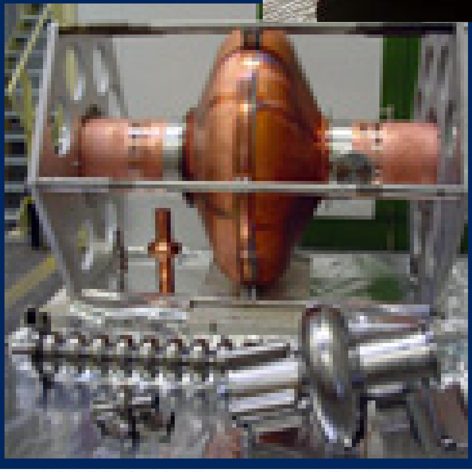
Science Goal "Push"								Application "Pull"				
High Energy	Beam Power	Beam Emittance	High Gradient	New Methods	Brightness & Coherence	Compact Accelerators	DOE R&D Program Thrust ~$140M	Industry	Medicine	Energy and Environment	National Security	Discovery Science
●	●		●			●	Superconducting RF	●		●		●
●	●	●		●	●		Accelerator, Beam, Computation			●		●
	●	●			●		Particle Sources	●		●	●	●
●	●		●				RF Sources	●		●		●
	●	●			●		Beam Inst. & Controls		●			●
			●			●	NC High-gradient Acc. Structures	●			●	●
●						●	New Accelerator		●			●
●		●					Superconducting Magnets		●			●

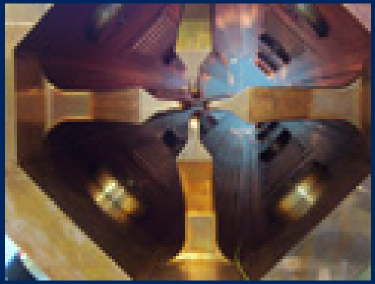
Feedback

Previously successful R&D









Accelerators in the market place

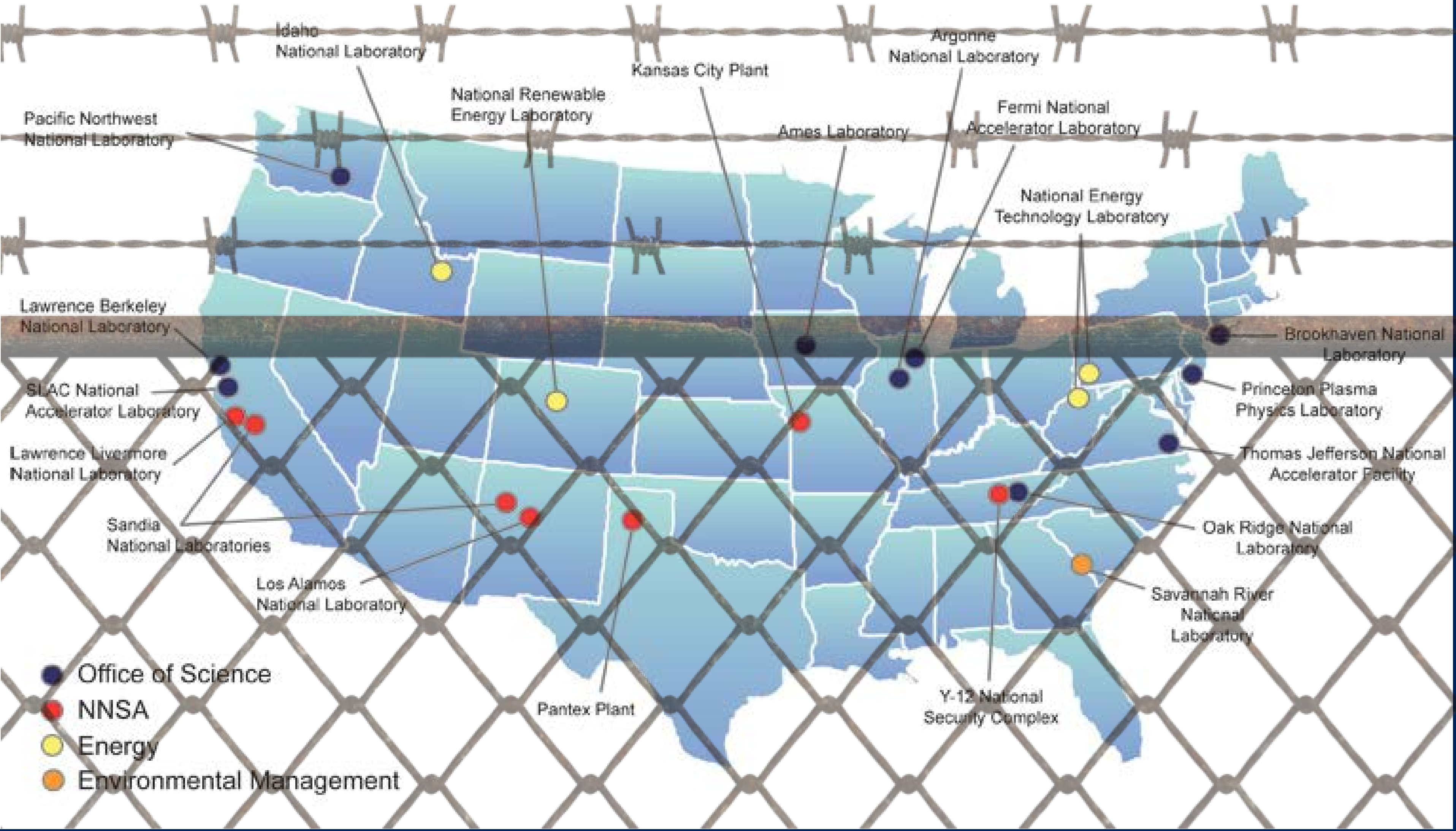
Courtesy: R. Hamm

Accelerator business segment	US Vendors	Annual Revenue*	No. of US Employees*	Foreign owned vendors in US
Electron cancer therapy	Varian Medical Corporation	$2,340M	5200	
Radioisotope production	GE Medical (Sweden)	$120M	100	Siemens Healthcare, AccSys Technology, Inc.
Ion implantation	Applied Materials Corp.	$1,200M	1500	
Neutron generators	Thermo Scientific, Adelphi Technology, Inc.	$25M	150	
MRI systems	Fonar Corporation, GE Healthcare	$1,500M	2000	
Medical imaging detectors	Ortec, Amptek, Canberra	n/a	n/a	
Ion Beam Analysis	National Electrostatic Corporation	$20M	100	
Electron beam NDE	Varian Security & Inspection Products, L&W Research Corp., HESCO	$110M	150	
* Estimates from author		$5,315B	9200	

Historically, this is how the labs have viewed industry…

Courtesy: Eric Isaacs

…and this is how industry has viewed us.



Courtesy: Eric Isaacs

What do we have so far:

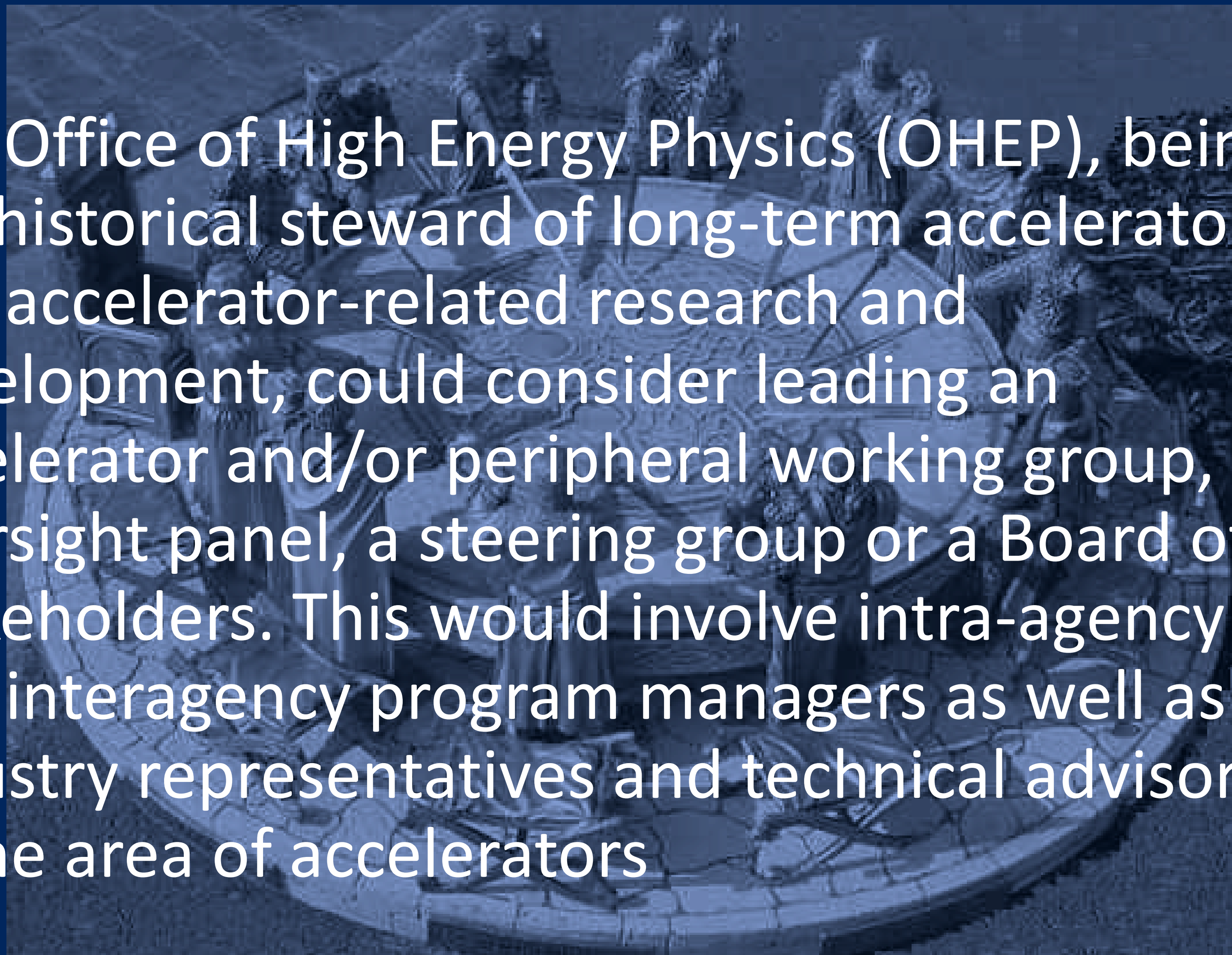
- I will go over a couple of major ideas that a more general and address questions of impediments to success and major programs to look for.

- Some of them are DOE specific: Others are shared with NSF and NSF would bring a lot of strength

- We have had teams working on:

  Discovery Science/Education: G. Hoffstaetter, M. White
  Energy/Environment: S. Henderson, F.Pilat
  Medicine: L. Boeh, J. Clayton, S. Gourlay, G. Zdasiuk
  Defense: S. Biedron, S. Milton
  Industry: R. Hamm, L. Merminga, S. Ozaki,

“The Round Table”



The Office of High Energy Physics (OHEP), being the historical steward of long-term accelerator and accelerator-related research and development, could consider leading an accelerator and/or peripheral working group, an oversight panel, a steering group or a Board of Stakeholders. This would involve intra-agency and interagency program managers as well as industry representatives and technical advisors in the area of accelerators

Communicate what is there and how to use it

National laboratories, user facilities and other accelerator R&D facilities of the Office of Science would all benefit from more direct and open communication. This would include the development of simple user-friendly procedures to give customers (for example, other agencies and industry) access to national laboratory infrastructure (computing centers, test facilities, test stations and technology infrastructure) and, equally importantly, to expertise (people and results). This could include the provision to perform proprietary research, or at least research in access-controlled areas. In many cases the use of this infrastructure could be modeled after well-established principles from BES user facilities and represented by the National User Facility Organization (http://nufo.org/).

Concerns of our industrial partners

The Office of Science/OHEP can work to identify, understand and resolve the concerns from industry and other agencies regarding protection of incoming and generated intellectual property or information. It would be useful to have, for this purpose and as a basis, a template applicable to all user facilities and infrastructures at Office of Science national laboratories. Such templates could cover all aspects of a contractual arrangement that is typically negotiated every time an arrangement is put in place.

Leveraging where possible

Leveraging the SBIR/STTR funding with a specific focus on energy and environment, medicine, industry and defense and security apart from discovery science could strengthen these parts of the program, providing an easy way to direct some money towards the topic areas identified in the Accelerators for America's Future workshop

Collaborative Accelerator Research Teams CARTs

The Office of Science OHEP's wealth of knowledge and vast infrastructure could be channeled to establish Collaborative Accelerator Research Teams (CARTs) focused on specific challenges detailed in the Accelerators for America's Future workshop. OHEP, with its stewardship program as well as the other directorates through its national laboratories, could direct its capabilities towards specific issues in the areas of energy and the environment, medicine, industry, defense and security and discovery science. The interdisciplinary Teams, drawing from national laboratories, other agencies, industry and universities, would have a clear mission, a finite duration and are competitively bid.

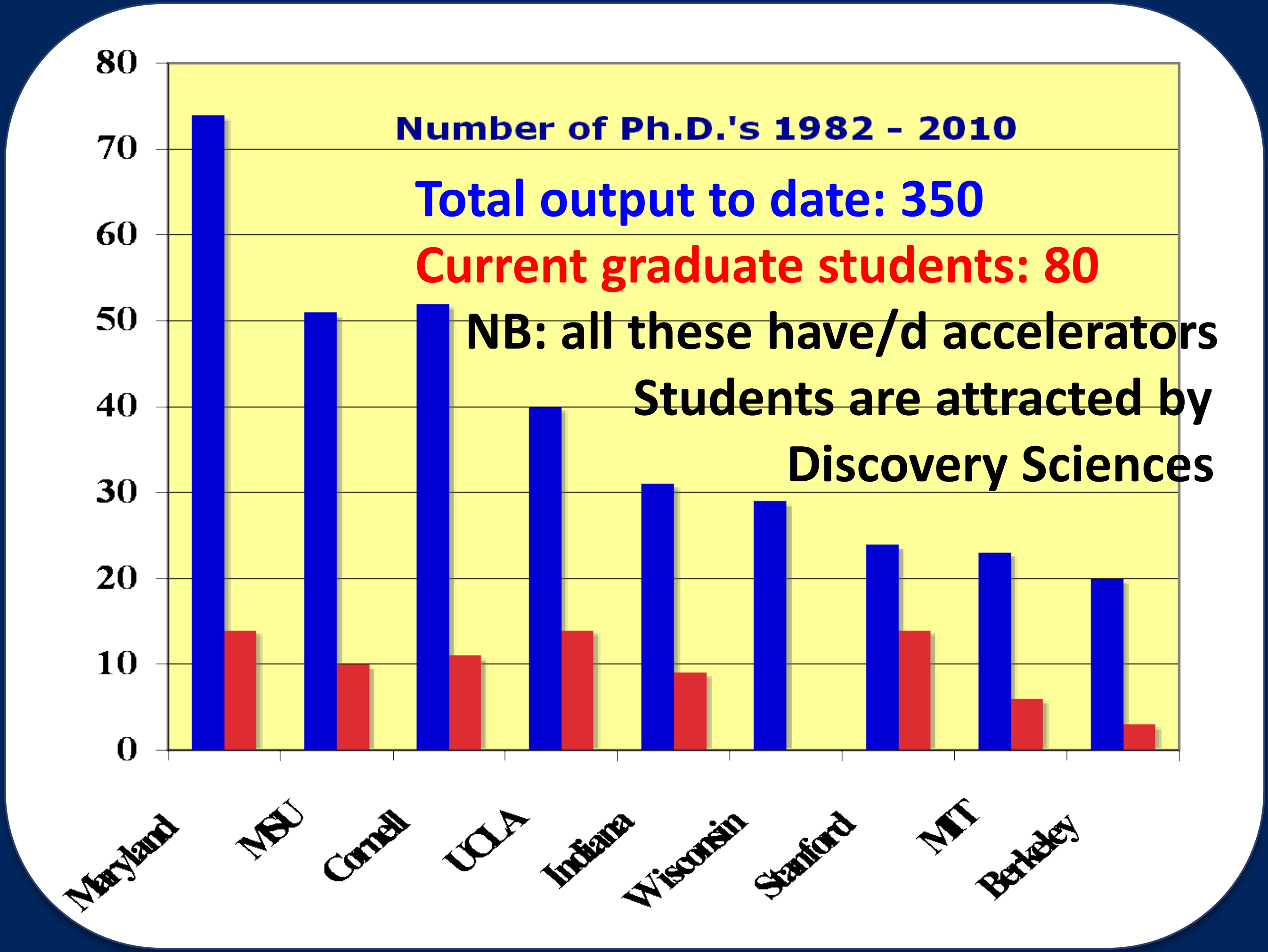
A new Program within Advanced Accelerator R&D in OHEP

The Office of Science could establish a program with the purpose of bringing industry, laboratories and universities together to foster the application of accelerator technology in energy and the environment, industry, medicine, defense and security and discovery science.

Accelerator Education is a must!

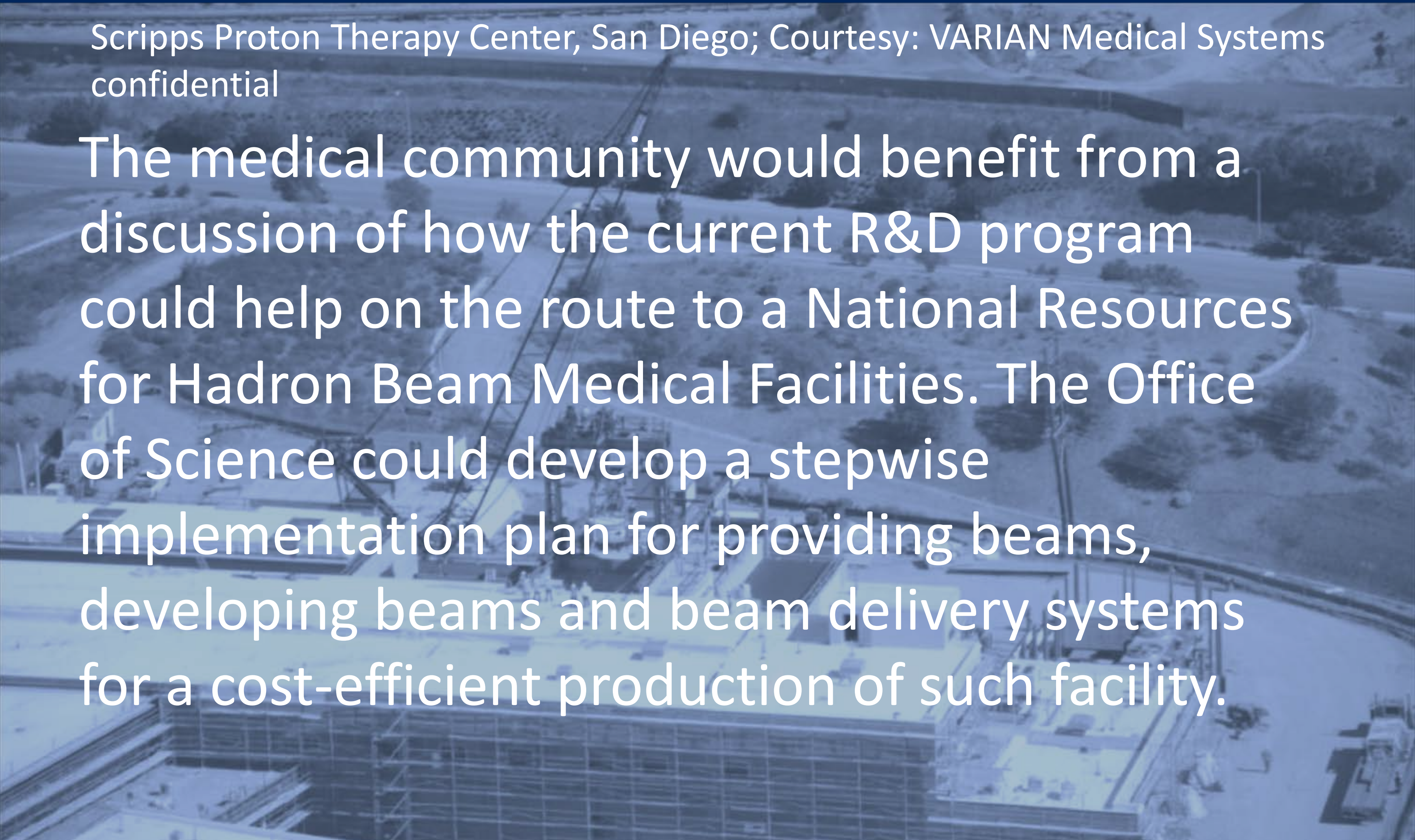
The particle accelerator workforce would significantly benefit from an extension and addition to what is currently available in education programs. Workforce development for particle accelerator R&D has traditionally been a major emphasis of the Office of Science, and in particular, the HEP and some of the NSF programs. Though close contacts between universities and national laboratories exist, the Office of Science could help involve more universities in accelerator education programs. It could also facilitate more integration with industry, giving it easier access to these programs.

PhD output for accelerators in the US



Education at operating accelerators with student access and R&D is needed.

Infrastructure Proposal 1

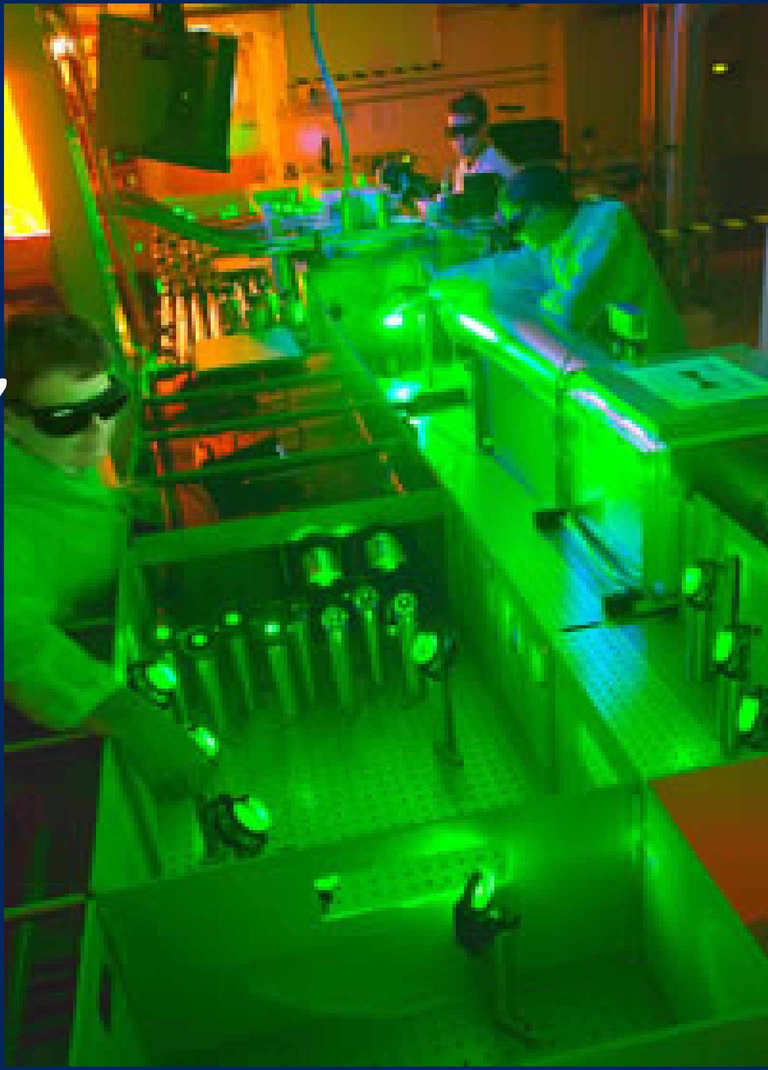


Scripps Proton Therapy Center, San Diego; Courtesy: VARIAN Medical Systems confidential

The medical community would benefit from a discussion of how the current R&D program could help on the route to a National Resources for Hadron Beam Medical Facilities. The Office of Science could develop a stepwise implementation plan for providing beams, developing beams and beam delivery systems for a cost-efficient production of such facility.

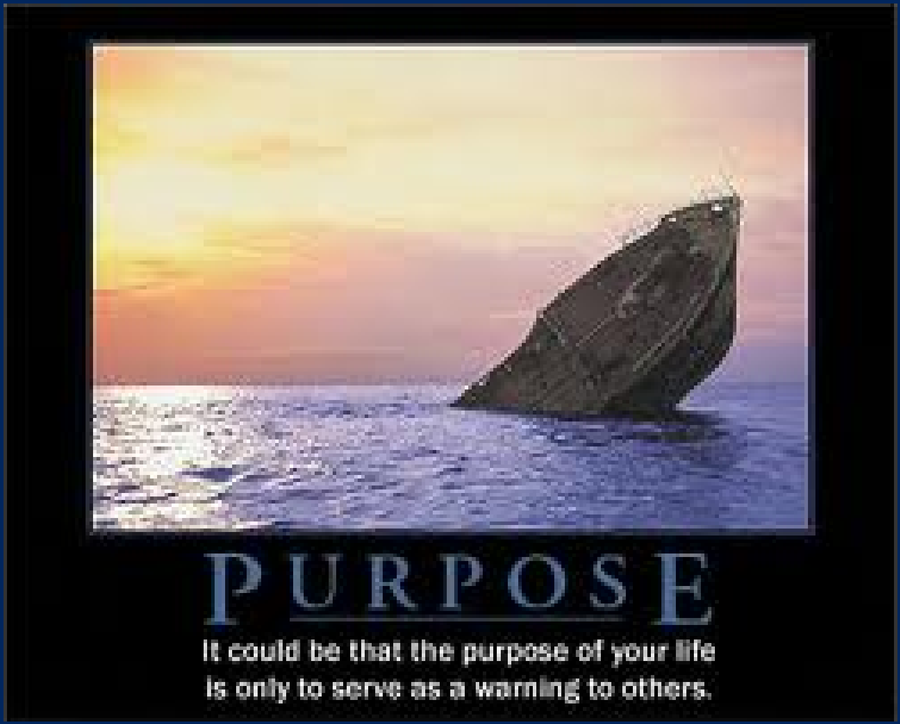
Infrastructure Proposal 2

The Office of Science could consider providing a home for laser R&D under its auspices. Lasers, an enabling technology, have become an integral part of accelerators and provide tremendous potential for new methods of acceleration, for miniaturization of accelerators and as part of accelerator systems.



Summary

- Congress is waiting for an answer and I hope we are helpful
- We need advise on feasibility, appropriateness and content
- Implementing some of the ideas would mean to do business a bit different.
- Of course we hope that our input will last a bit longer and go deeper than some of the other panels. But that needs all/most of OS on board



Backup

US Department of Energy Accelerator R&D Task Force

Pages concerning NSF

March 9, 2012

Important points to make early on

1) The NSF has been an essential supporter of forefront accelerator R&D, and continues to have a crucial role.
2) While this has mostly been motivated by discovery science, this support lead to industrialization, e.g
a) Superconducting cyclotrons for medicine
b) Commercial SRF cavities for light sources

3) NSF's educational mission in accelerator R&D has been essential for accelerators at all US agencies.

4) NSF has started an education program that is to bridge the gap between universities and industry

The NSF has to play crucial roles in US accelerator R&D

Essential Accelerator R&D from NSF

A few examples that illustrate the essential role NSF has planed in US accelerator R&D

SRF

- Since 1965, now industrialized
- NSF was a frontrunner in this technology, long before other agencies (particularly at Stanford and Cornell)
- Now used for discoveries in many light sources, nuclear physics, in neutron spallation, and in colliders
- Efficient Nb on Cu cavities for the Muon Collider

Superconducting magnets

- Immediately transferred to MRI
- NSF was a frontrunner in this technology for cyclotrons (particularly at the NS
- Superconducting cyclotrons for hospitals
- Now used for discoveries in colliders and light sources

High luminosity colliders, beam cooling, and polarized beams

- World record luminosity (particularly in CESR for a full decade)
- Electron cooling (particularly at the Indiana University)
- Polarized beam dynamics (particularly at Indiana University)

The NSF has been a leader in accelerator innovation, bringing technology to fruition through decades of R&D

Education and Workforce development for accelerator physics and technology

- NSF provides dominantly for education of accelerator experts.
- Essential is education at universities with hands-on accelerator operation – needs to be continued.
- HR departments of accelerator labs continuously report a shortage of experts for accelerator R&D and operation.
- 55000 peer-reviewed papers with accelerator as a keyword can be found on the web, but only few universities have a program.
- 6 Universities have 2 or more faculty and regular education programs and research
- 3 are establishing a program
- 11 Universities have on active faculty member but no lectures
- US PA School offers two accelerator schools per year at changing locations, 150 students each.

Education efforts need to be maintained and extended, particularly by NSF

Vision for expanded education

- Continued support for accelerator education, particularly at universities where students can have hands-on access to accelerator operation.
- NSF has an essential role for educating the US accelerator experts.
- Continued support for US Particle Accelerator School (USPAS) and for students at conferences
- Student fellowships allow more universities to become involved
- New universities will coordinate with accelerators that have student access, i.e., preserve accelerators at universities
- Contacts between universities and labs exist and already provide a good professional pathway
- Pathway from university to industry needs to be fostered, for example, by support for internships in industry, industry participation in the USPAS, industry sessions at conferences

Continue support of workforce development at excellently equipped and capable educations institutions.

Summary of accelerators for discovery science

- Much of today's and tomorrow's basic knowledge of nature is due to accelerators. Advanced Accelerator R&D in many cases prepared the ground for new developments
- Historically, the US has been a global innovating force for accelerators, with world experts and great facilities
- Coordination and collaboration between existing facilities may optimize output
- Construction and support of the necessary dedicated accelerator research and development facilities will help ensure US leadership role in the future
- Support of accelerator educational opportunities is key to maintaining a healthy, vibrant US program

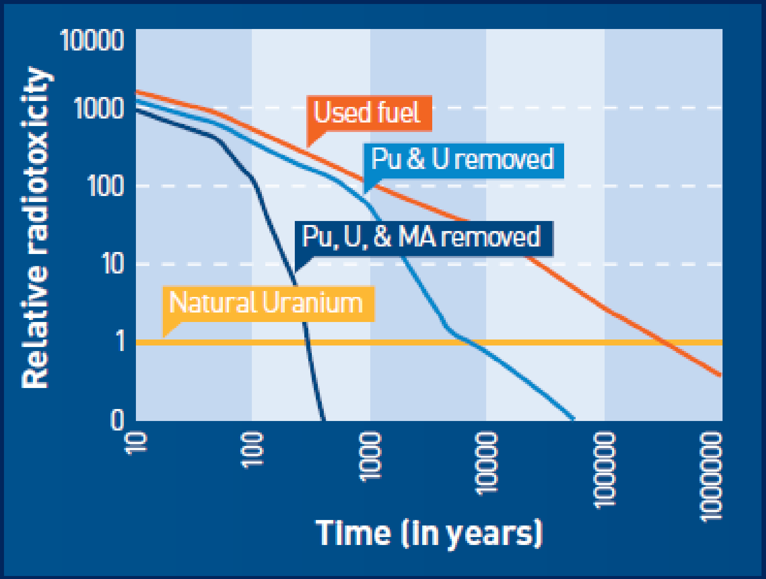
The US has a brilliant history, excellent experts, and forefront facilities to launch the next generation of discoveries

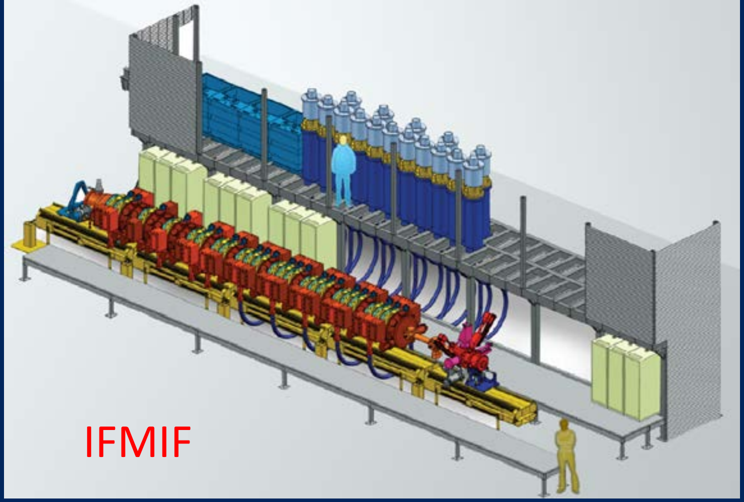
Other examples: Defense

- Directed energy: Navy free electron-laser
  - Current version is only a prototype
  - Future versions will most likely learn from and then improve significantly on the prototype
- Advanced stockpile stewardship and materials characterization
  - Spallation neutrons
  - Very hard-energy XFEL
  - Radiography
- Compact system development
  - For homeland security
  - For directed energy
  - Counter-proliferation

Other Examples: Energy

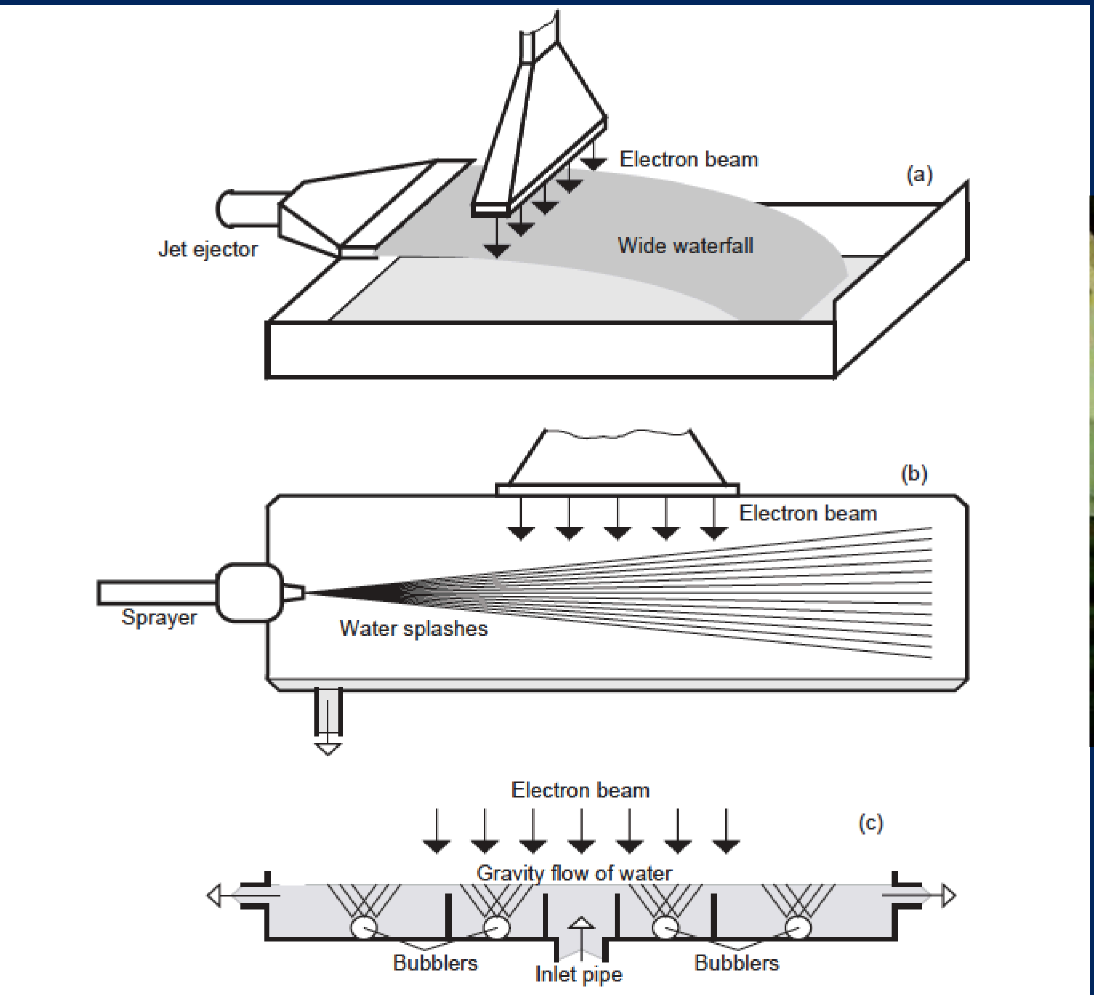
- Accelerators open up new possibilities for advanced nuclear fuel cycles
  - transmutation of waste
  - power generation using Th fuel, or breeding fissile material for subsequent use in critical or subcritical reactor systems





- Accelerator-based irradiation facilities to provide environments relevant for advanced nuclear energy systems for fusion and fission

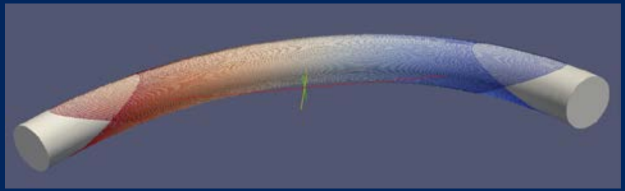
Other Examples: Environment

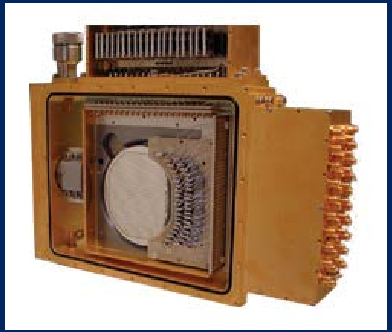


Other Examples: Medicine

Radioisotope production

- Augmentation of existing facilities – depends on extent to which programs are willing to redirect



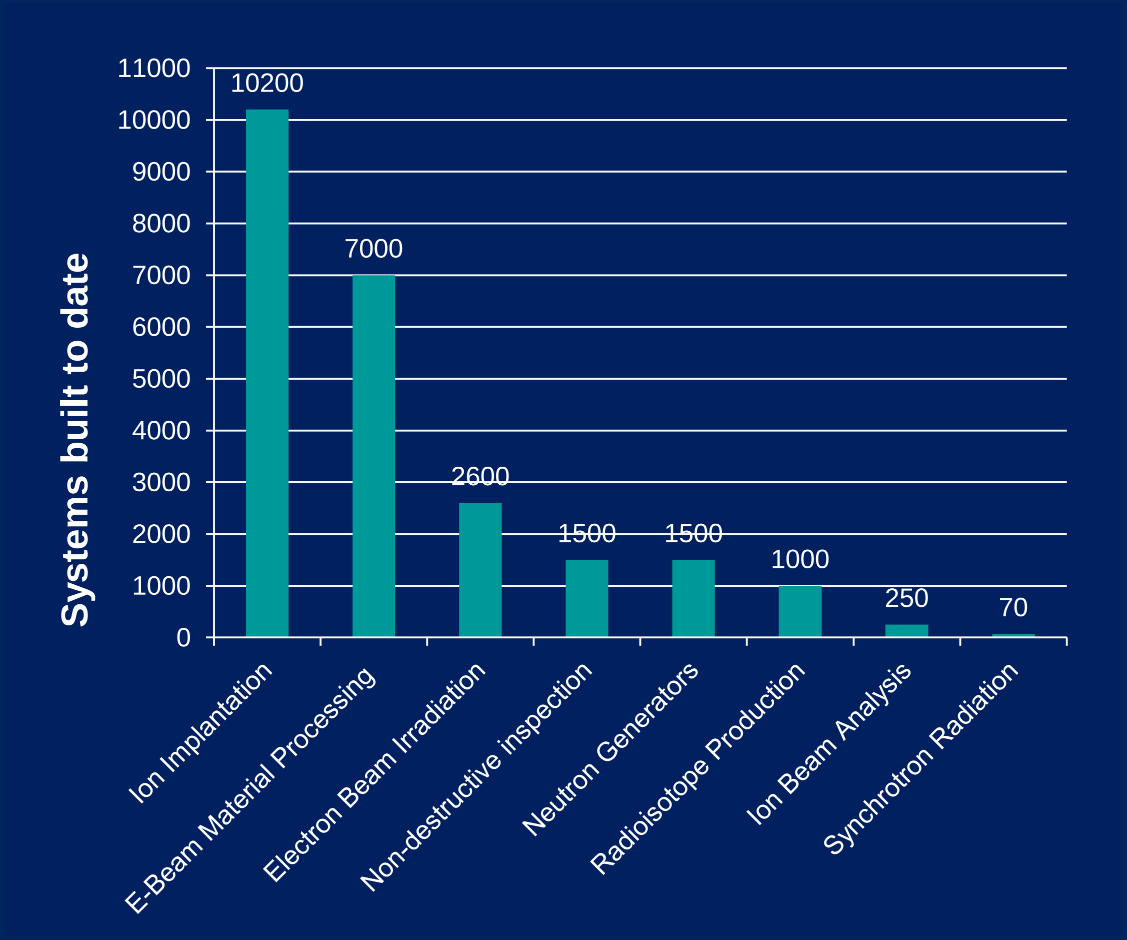


Beam therapy

- Integration of existing technology into facility design (~$2 M)
- Joint agency project to build one or two research facilities (east and west coast)
  - Total cost ~$200M = $120M public/private + $80M DoE + OPS (NIH?)
  - Includes evolutionary technology: beam delivery, gantry, state-of-the-art controls with hooks for future upgrades

Research facility for treatment with protons, clinical trials, radiobiology, and accelerator R&D is needed

Other Examples: Industrial applications



- Total built to date >24 000, with >18 000 in operation
- Sales increasing ~10% per year
- Presently >70 accelerator vendors worldwide
- Vendors primarily in US, Europe and Japan, but growing in China, Russia and India
- Equipment sales ~$3B per year worldwide

All the products that are processed, treated or inspected by particle beams have an annual value exceeding $500B

Accelerator R&D

SC Program Contributions

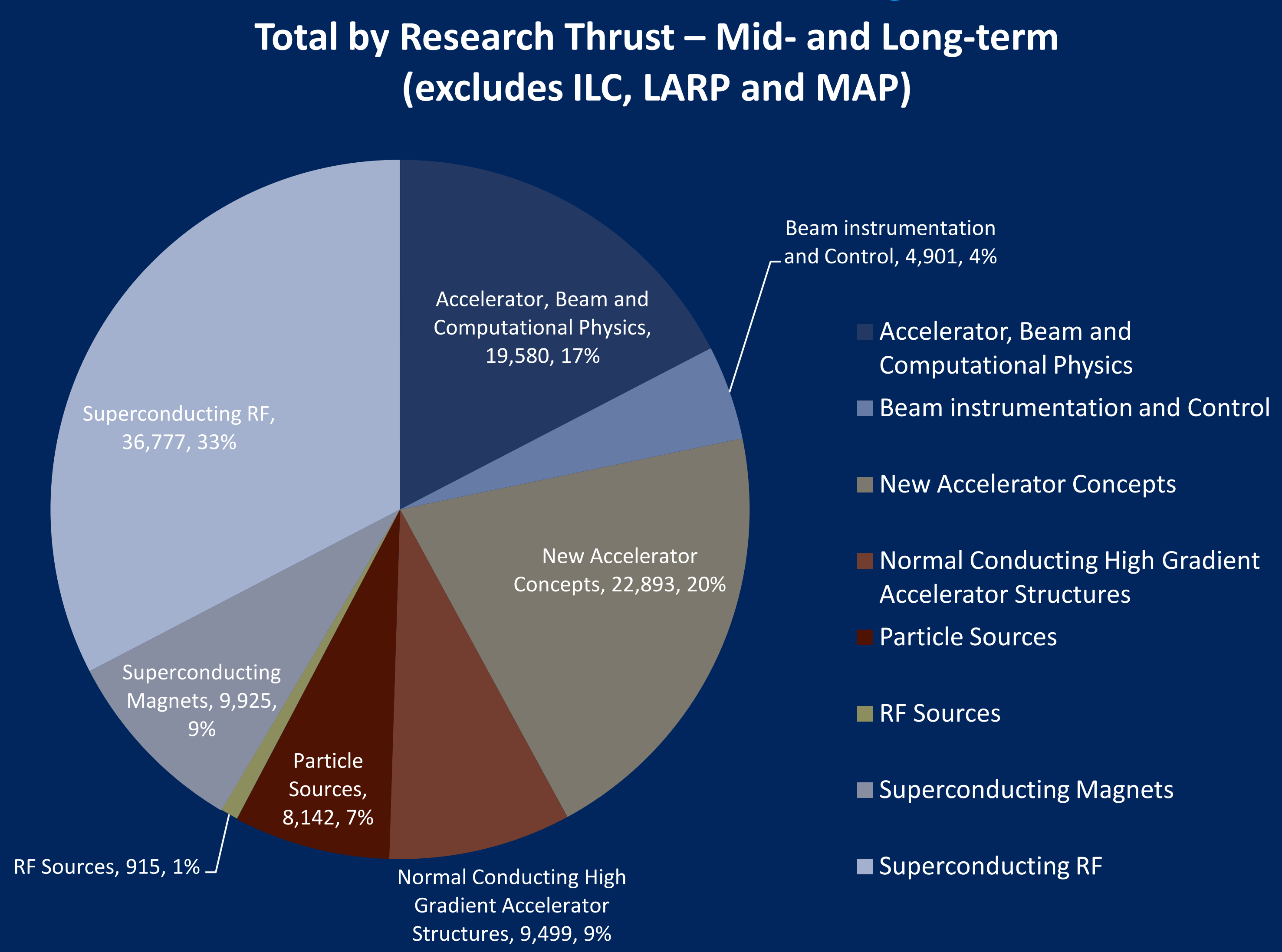
Courtesy: M. Procario

Programs	Mid-term (facility-driven) R&D	Long-term (accel. science-driven) R&D	Directed R&D Campaign	Total
ASCR	550	-		550
BES	10,646	-		10,646
HEP	51,091	41,600	51,521*	144,212
NP	8,745	-		8,745
Total	71,032	41,600	51,521*	164,153

* ILC (28,288), MAP (10,882) and LARP (12,351)

Does not include very short-term R&D done on facility operations budgets

Accelerator R&D – By Thrust



Courtesy: M. Procario; from a recent briefing to Bill Brinkman

Accelerator R&D Inventory

SC Program Participation by labs and thrusts

Thrust / Inst.	Beam Physics	Beam Instr/ctl	New concept	NC high grad. RF	Particle sources	RF sources	SC magnet	SC RF
ANL	ASCR ⊙ NP ◉		HEP ●	HEP ◉	HEP ◉ NP ⊙			HEP ◉
BNL	BES ◉ NP ◉	NP ●	HEP ●	HEP ◉	BES ◉ HEP ◉		HEP ◉	NP ●
FNAL	HEP ●	HEP ●			HEP ●		HEP ●	HEP ● NP ◉
JLAB	NP ◉				NP ◉			BES ● NP ●
LBNL	ASCR ⊙ BES ◉ HEP ●	HEP ◉	HEP ●		BES ●		HEP ●	
PPPL	HEP ⊙							
SLAC	ASCR ⊙ BES ● HEP ●	BES ◉	HEP ●	HEP ●	BES ◉	HEP ◉		
UNIV.	BES ● HEP ●	HEP ◉	HEP ●	HEP ●	BES ◉ HEP ⊙ NP ◉		HEP ●	HEP ◉

Key: 100<⊙<300; 300<◉<1,000; ●>1,000 (FY11 $k) Color code: ASCR; BES ; HEP ; NP

More recent Technology Transfer Companies

Courtesy: R. Hamm

New technology transfer companies	Application area	Employees	Annual Revenue
Accuray	Medical	1100	$285M
Niowave.	Industrial & discovery science		
Radiabeam	Industrial & discovery science		
Lyncean Technologies	Medical		
Mevion	Medical		
CPAC	Medical		
XScell (formerly SRC)	Industrial		
Adelphi Technology, Inc.	Industrial		
AccSys Technology, Inc.	Medical & industrial		
	Total	1385	~$310M

A Service to the Complex and the Nation

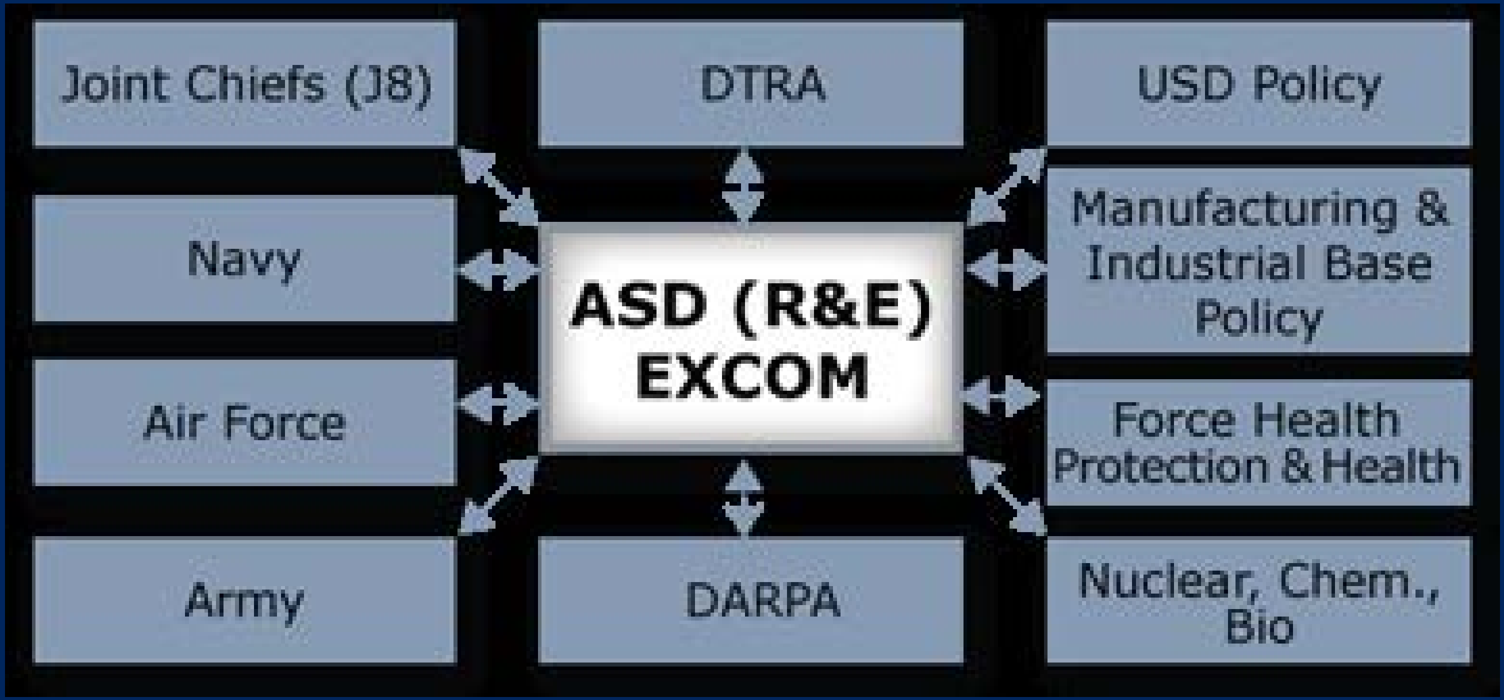
DOE Accelerator Facilities Are Heavily Dependent on High Power RF Technology

- Many of these accelerators will operate for decades, but have no or very limited in house capability
- Continued operation depends on the availability of products from a risk-averse industry that has downsized to 1.5 US companies over the past 2 decades.

Laboratory	< 50 MHz	200 MHz	400 MHz	700 MHz	800 MHz	1.3 GHz	2.856 GHz	11.4 GHz
Argonne			■				■	
Brookhaven	■	■					■	■
FNAL	■	■			■	■		
LBNL			■			■		
LLNL								■
LANL		■		■	■			
ORNL			■		■			
SLAC		■	■	■		■	■	■
TJNAF						■		

Summary of high power RF sources and technology used at DOE laboratories to power accelerators. Green boxes denote the approximate frequencies

Executive Committee in the Defense World



Anyone seen the lifejackets?